worthy and interesting feature is the fact that a comparison of figures 6 and 7 as of 5 and 6, shows no increase in the average height of maximum frequency with decrease in latitude. Comparison of figures 4, 5, 6, and 7 shows that the level of maximum frequency of the lowest cloud type occurs at about 350 to 400 meters above the surface, regardless of season or latitude, and that the same disregard to season or to latitude applies equally to the higher St. Cu. and Cu. types

Figure 8.—On this is charted over 5,500 observations of all cloud types during all seasons, and at widely distributed stations representing all latitudes and longitudes throughout that portion of the United States east of the Rockies. This chart is the nearest answer yet possible from existing data to the question of the average actual distribution of levels of maximum or minimum frequency of condensation. A cursory examination will show quite distinctly a level of maximum frequency in this group of observations, corresponding to the stratus level, at 350 to 400 meters. The more gradual slope above this level is due to the fewer cumuli and their higher levels. It might therefore seem from this that there actually exists only one level of maximum frequency of condensation, corresponding to that of maximum frequency of the stratus cloud base, and that, consequently, the regions on either side are regions of decreasing cloudiness, or condensation.

Figure 9.—This chart represents a departure from the other cloud charts in that the data made use of in constructing figure 9 were gathered from observations partly from European stations, grouped regardless of cloud type, season, or geographic location, as in figure 8; but, unlike figures 1 to 8, they show only mean values between small, though arbitrarily selected limits. These data, however, as used by Clayton in his cloud studies,[7] show substantially the same general features as figure 8, with the single exceptions that the level of maximum frequency is somewhat higher than that shown by figure 8, and owing to the far greater number of observations of higher clouds (in the cirrus region), there appears to be a region of maximum frequency somewhere within the limits of 6,500 and 8,500 meters. Thus far, then, this chart agrees more closely with the theoretical regions of maximum and minimum condensation to which numerous references have been made. But even this fails to indicate two regions of maxima corresponding to the so-called "foul-weather" and "fair-weather" cumuli, with the consequent "intercumulus" region of minimum condensation.

CONCLUSION.

It must be admitted that the theoretical distribution of maximum and minimum condensation in the main seems logical and, in spite of *frequency* alone not showing them (frequency × amount of cloudiness), which has not been considered here, would probably prove its correctness.

From a cursory inspection of the foregoing cloud charts and a hasty consideration of the interpretation thereof, one might arrive at the conclusion that such charts furnish conclusive evidence that only one appreciable region of maximum frequency of condensation actually exists in the upper air, and that the region on either side is one of decreasing condensation. Indeed, this view seems quite tenable. But, in the light of the meager data available, and of our very inadequate methods of procuring thorough and reliable observations at all altitudes simultaneously and in all conditions of weather, such a conclusion may not be considered as final. There are many substantial reasons which compel us to suspend judgment for the present at least, and to await future development of new and more complete methods of cloud measurement:

(1) Our measurements of clouds refer mainly to their bases. Few measurements of cloud thickness or of cloud density have been made, owing to lack of convenient methods. Since, therefore, our present knowledge of these interesting conditions is extremely meager, and since, too, the level of maximum density would not necessarily be at the cloud base, the association of cloud base and "level of maximum condensation" is unwarranted and most likely erroneous; for a complete observation would include thickness or depth of clouds in order to locate the regions of maximum condensation.

(2) Kite flights never reach into the cirrus levels, and not very frequently do they penetrate the higher alto-stratus and alto-cumulus levels. Practically all our observations of these higher cloud forms have been made with balloons, and it is not very frequently that a pilot balloon can be followed till it reaches these higher (cirrus) regions. So these handicaps to the measurement of all the higher cloud forms prevailing at the time of observation would tend to show a minimized prevalence of upper clouds as compared with the lower types.

(3) As is self-evident, when the sky is overcast with lower clouds the kite and pilot balloon methods of measurement fail to enable us to observe the higher forms simultaneously with the lower, or to ascertain whether there exist simultaneously alternate intermediate regions of relatively dry air between the upper and lower cloud strata.

(4) It is obvious that our cloud charts as they now stand do not prove or disprove conclusively that more than one region of maximum condensation exists; nor can we hope to get much nearer our goal until some more satisfactory method is inaugurated for observing all clouds regularly and simultaneously, that happen to exist at the specified times of such observations, which should be sufficiently distributed equally to include all types. We can only draw our own personal inferences from what we have before us, and this is left to the reader. They do, however, seem to justify the conclusion that at least one, and possibly two, regions of maximum *frequency* of condensation exist.

Moreover, the observations seem to establish the fact quite conclusively that neither latitude nor season produces any appreciable change in the average altitude of the lower clouds, as is supposed to be the case with the higher clouds.

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THE VERTICAL EXTENT OF CLOUD LAYERS.[1]

By W. PEPPLER.

[Abstracted from *Meteorologische Zeitschrift*, January, 1921, pp. 18–21.]

This paper is a continuation of the discussion of measurements upon clouds at Lindenberg, covering a period of 11 years of observations with kites and captive bal-

[7] *Ibid.*, p. 334.

[1] *Die vertikale Erstreckung der Wolkenschichten und die Wolkenlagen über Lindenberg.*

loons. This note is concerned chiefly with the mean thickness of cloud layers. The results for the different cloud types are as follows:

Stratus.—Thickness less than 400 meters in greatest number of cases; very seldom greater than 600 meters; mean thickness, 320 meters. There appears to be little seasonal difference.

Nimbus.—The difficulties of observation are very much greater, but the mean thickness of 800 meters is obtained. This is based on a smaller number of observations, due to the fact that under conditions when nimbus prevail, ascents are difficult.

Cumulus.—89 observations gave a mean thickness of 500 meters.

Strato-cumulus.—This layer presented easier determinations because of the attendant discontinuities in temperature and humidity; layers less than 500 meters in thickness were predominant; mean thickness, 310 meters.

Alto-cumulus and alto-stratus.—It is seldon that this level was attained by the registering instruments, and often the clouds were of such a flaky character as to render determinations of thickness difficult; mean thickness for A. Cu., 120 meters, for A. St., 300 meters.

On the whole these values are not in bad agreement with those of Süring at Potsdam. From these means, and from the mean heights of the lower surface of the various cloud types, it is possible to construct a schematic vertical section of the atmosphere above Lindenberg. This the author does, and it appears that there are three layers in which the clouds do not frequently occur—designated by Wenger and Köppen as *wolkenfrei Räume*. These are (1) from the surface to 500 meters; (2) between 1,300 and 1,400 meters—this level being somewhat in doubt; and (3) between 1,900 and 3,000 meters. Too much weight is not given this diagram by the author, and he remarks that "it has only the value of a schematic representation of a cloudy day, but, owing to the numerous observations, it probably approaches closely to the truth."—*C. L. M.*

ANALYSIS OF CLOUD DISTRIBUTION AT ABERDEEN, SCOTLAND,[1] 1916–1918.

By G. A. CLARKE.

[Reprinted from *Science Abstracts*, Sec. A, Jan. 31, 1921, §36.]

The cloud distribution is analysed from the point of view of aerial navigation. Cloud observations are taken at Aberdeen at 7h., 9 h., 13 h., 15 h., 18 h., 21 h., and to each day is assigned in addition a "cloud characteristic" indicating the kind of cloud which predominated, the lowest type taking precedence over higher ones if covering four-tenths of the sky or more. The day is "clear" if on the average the total amount of sky covered is less than four-tenths, while certain days of very mixed or rapidly changing cloud are classed as "various." Taking cumulus and cumulo-nimbus together, they are found to give the most frequent skies, 23 per cent of the total, while other low clouds are numerous. Alto-stratus skies are twice as frequent as alto-cumulus, but cirro-stratus and cirro-cumulus skies are of equal frequency. Using the average heights of the various types together with the cloud characteristic, 15 per cent of days are seen to be cloud-free below 15,000 feet, 26 per cent below 7,000 feet, 69 per cent below 3,000 feet, while the remaining 31 per cent of days have cloud predominating below 3,000 feet. Seasonal distribution is discussed. The frequency of cumulus and cumulo-nimbus taken together is found to be greatest in April, and there are secondary maxima in mid-summer and September. Air conditions should be most bumpy at these periods. Strato-cumulus skies are more common in winter than in summer, and there are indications that skies well covered with intermediate and higher clouds are also more frequent in winter, but the observations depend on the presence or absence of lower cloud.—*M. A. G.*

[1] Meteorological Office, London, *Professional Notes No. 9*, 1920, pp. 142–147. Cf. also, Brunt, D.: On the inter-relation of wind direction and cloud amount at Richmond (Kew Observatory), *ibid.*, No. 1, 1918, 11 pp.; Diagrams illustrating the amount of cloud during summer and winter with winds from different directions, at Kola and Archangel, *ibid.*, No. 7; The Climate of Northwest Russia, 1919, p. 94; Brunt, D.: Tables of frequencies of surface wind directions and cloud amounts at Metz, Mulhausen, Karlsruhe and Frankfurt, *ibid.*, No. 14, 1920.

THE ARGONNE BATTLE CLOUD.

By B. M. VARNEY.

[University of California, June 22, 1921.]

Descriptions of unusual clouds that were formed in the wakes of airplanes flying over the Argonne battle front in the autumn of 1918 has since been published by eyewitnesses. Mr. G. B. Vaughn wrote [1] as follows:

> We were passing through a little town * * * when we noticed three parallel lines of clouds or smoke stretching far across the sky. They looked as if they had been made by three planes passing, throwing out smoke and cutting stunts, for the lines were far from straight. Through these lines were waves which ran perpendicular to the earth, with a drift from left to right. They looked most like waves of heat one sees rising from the earth, but they traveled with a shifting motion somewhat like the flickering of the northern lights.

Capt. W. F. Wells, Sixtieth Infantry, American Expeditionary Forces, wrote: [2]

> There were two or three days of rain, when came a wonderfully clear and beautiful morning, with not a cloud in sight. * * * Our attention was first drawn to the sky by the sudden appearance of several strange and startling clouds—long, graceful, looping ribbons of white. These were tapering to a point at one end, and at the other, where they dissolved into nothingness, sixty degrees across the sky, were about as broad as the width of a finger held arm's distance from the eye. On close observation we noticed some distance ahead of each cloud point the tiny speck of a chase plane. Apparently the churning of the air was all that was needed to upset the delicately balanced meteorological conditions and precipitate this strange cloud formation. * * * Never before had I seen a plane writing in white upon the blue slate of the sky.

Capt. W. H. Nead, One hundred and sixty-eighth Infantry, described the phenomenon [3] thus:

> The Rainbow Division, on the morning of October 10, 1918, was lying in what had at one time been a wood just back of Montfaucon. The sky was clear except for a few fleecy clouds to the northwest. Three airmen came from the northwest and passed almost over our regiment, continuing on to the southeast.
>
> Behind each machine was a trail of white, which at first sight appeared to be smoke resulting from poor engine combustion, but which upon more careful observation proved too wide to have been caused by smoke. Perhaps the strangest thing of all was the fact that when the planes reached a certain point in the sky the rainbow (sundog) colors became distinctly visible.
>
> The explanation is not difficult. The air was almost saturated with moisture at the temperature which prevailed at that altitude. With the passing of the planes, the propeller movements caused a strong air current with a lowering of the temperature where the current was noticeable. With the lowering of the temperature the air became supersaturated with moisture, forming a small cloud, which at that altitude immediately became snow. This snow would give the white appearance * * * and would also account for the rainbow colors.

The attainment of the saturation point being necessary to condensation, the methods by which this may be

[1] *Am. Legion Weekly*, Sept. 24, 1920, p. 28.
[2] *Scientific American*, June 7, 1919.
[3] *Am. Legion Weekly*, Oct. 22, 1920, p. 12.